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Editorial

Protecting water quality of the Florida Everglades: Sustainably achieving low phosphorus concentrations with wetlands

1. Introduction

The Florida Everglades is in the middle of a restoration (often referred to as the Comprehensive Everglades Restoration Plan (CERP)) that is projected to ultimately cost US$20 billion (National Research Council, 2014). The restoration features enhancing the hydrologic fluxes of overflow water from Lake Okeechobee back to a north-south flow pattern through the Florida Everglades, while, just as importantly, making sure that this water meets rigorous water quality standards for nutrients, particularly phosphorus, before the water enters the oligotrophic Everglades sawgrass (*Cladium jamaicense*) "river of grass" (Mitsch and Gosselink, 2015).

The overall progress of this Everglades restoration, probably the costliest ecological restoration project ever undertaken in the world, has been challenged recently in several forums. Mitsch (2014) described the progress of the Florida Everglades Restoration and the equally complex Louisiana Delta Restoration in this way:

> Two projects with similar large scales, immense budgets, complex hydrology and landscape issues, and enormously complex local politics, all of which do not sync well with sustainability, are the Florida Everglades Restoration and the Louisiana Delta Restoration in the wetland-rich southern USA. Each has also either been on the drawing boards or in practice for decades. I give the Florida Everglades project a slightly higher grade than the Louisiana Delta Restoration because the former has focused some of its resources on projects that will lead to positive outcomes—e.g., stormwater treatment wetlands for removing phosphorus from agricultural runoff and the elevating of *trans*-Everglades highways to once again allow north to south movement of water through the Everglades… But otherwise, despite enormous expenditures and plan after plan, neither project has resulted in the core hydrologic restoration that is needed

Independently, The National Research Council (National Research Council, 2014) concluded in their biennial review of the Florida Everglades Restoration that "restoration progress made by CERP [Comprehensive Everglades Restoration Plan] projects to date remains fairly modest in scope." In fact, the report noted that some of the most important progress was with the Kissimmee River restoration and a South Dade County spreader canal project, neither of which is formally part of the CERP. The NRC committee also noted a lack of appreciation of long-term changes in climate and sea level that are hardly mentioned in the restoration plan.

About that time, the public and many NGOs in the southern Florida were becoming impatient with the progress of the Florida Everglades restoration, particularly after an excessively wet summer of 2013 led to the discharge of 746,000 m^3 west from Lake Okeechobee down the Caloosahatchee River to the Gulf of Mexico and east down the St. Lucie Canal to the Atlantic Ocean coastline in water year 2013, a 160% increase from the previous water year (South Florida Water Management District, 2014). This water, sent east and west to the ocean instead of south to nourish the Florida Everglades as it did in pre-agro-industrial times, has also caused perceived and actual damage to the coastal estuaries. This public concern led to the 30th Annual Everglades Coalition conference in January 2015 in Key Largo, Florida, to have as its theme "Send It South: Water for America's Everglades." An even more disastrous flux to Florida's coastlines began in late January 2016 (Mitsch, 2016). By the end of 2016, 3 billion m^3 were discharged west and east to the Gulf of Mexico and the Atlantic Ocean coastal estuaries because of record rainfall in the usual dry season of January 2016 (Mitsch, 2017a). In July 2016, the Florida Governor declared a state of emergency over "guacamole-thick algae" in each estuary, ostensibly caused by the releases from Lake Okeechobee.

This background is important to describe the ecological and political setting before and after our paper (Mitsch et al., 2015) was published. Mitsch et al., 2015 presented optimism that it might be possible for additional ecologically engineered wetlands, such as those that are being used to improve the quality of the water that comes from Lake Okeechobee and especially runs off of the agricultural fields south of Lake Okeechobee (locally called STAs), to improve water quality close to an enigmatic 10 ppb phosphorus goal that has been decreed for decades as an ambitious goal for any water discharged into the Greater Florida Everglades. In Mitsch et al. (2015) and in the oral presentation of this paper first given in Nantes France in October 2013 and it the research report that we formally submitted two years prior to SFWMD (Mitsch et al., 2013), we stated:

> "Achieving 10 ppb phosphorus concentrations consistently from created wetlands in the Florida Everglades remains problematic but this research confirms that it may be possible with low loading rates, the right vegetation communities, and low nutrient soils."

In other words, we were and remain bullish about the already constructed and operating treatment wetlands (STAs) at the Florida Everglades.

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2. Replies to Julian, 2018

Julian (2018), with significant input from the South Florida Water Management District personnel, stated that their "commentary will discuss study limitations that could mislead readers to inappropriately apply results to current STA operations or future STA planning." We will speak to some of their criticisms here.

2.1. Ten ppb phosphorus "standard"

Julian (2018) presents an exhaustive description of the history of where the 10-ppb phosphorus concentration came from and how it should be applied. This is a useful history lesson and important to water quality managers and lawyers but of little relevance to our scientific paper. The 10 ppb, believed to be the historical maximum P input in Everglades (McCormick et al., 1999), was always a simple goal for our mesocosm project, based on many frequent references to it by our contract management personnel from the South Florida Water Management District (SFWMD). It remains the discharge standard to many NGOs and government agencies including the Florida Everglades National Park of the National Park Service. To us it was an ambitious goal and an easily remembered standard widely used but otherwise we were more interested in the phosphorus dynamics and retention in our model wetlands and a comparison of the original six vegetation "treatments" that were part of this study. When and even before our mesocosm study began in early 2010, 10 ppb of total phosphorus was one goal of the South Florida Water Management District, particularly since the outflow from an STA (our inflow water) was estimated to be about 30 ppb. [As it turned out the inflow phosphorus concentration to our mesocosms at end of our study averaged 25 µg-P/L (ppb, n = 55) (Mitsch et al., 2015).]

2.2. Experimental design

Julian (2018) spends several paragraphs discussing our experimental design. The choice of vegetation communities and even the loading rates were pre-determined by SFWMD personnel given that our study goal was to further reduce P concentrations from the STA outflow using native vegetation communities. The prime author of much of the experimental design at the SFWMD wrote a non-peer- reviewed agency annual report chapter of the same contractual study (Miao, 2015) for which we submitted the official final report two years earlier (Mitsch et al., 2013).

There are other issues about our experimental design raised by Julian (2018):

- Julian (2018) discusses "pre-treatment" of the 25-ppb phosphorus inflow water, which makes no sense and would have tripled the cost of this modestly funded experiment.
- Julian (2018) describes the soil that was used in the study as "moderately high P concentrations and rates of P release." We knew that and had said so in our quarterly reports, our final report, and in Mitsch et al. (2015). The soil came from the outflow area of an adjacent STA. This was and remains a logical decision as this is exactly the soil that would probably be used if additional STAs are constructed someday downstream of the existing STAs.
- Julian (2018) believed that we should have done a 2-year preparation of the soil to exhaust the soil phosphorus to "equilibration" before we began our experiment. In fact, that is what we did. The first 1.5 years of nutrient sampling in our experiment showed that outflow concentrations of phosphorus exceeded inflow concentrations. Our finding that the mesocosms and hence any wetland constructed to achieve low concentrations of phosphorus might take several years to even be net sinks of phosphorus was enlightening and we believe that finding alone was worth the entire cost of this study. Additionally, our results represent what would likely happen when wetland or other best management practices were implemented in field conditions, since there is no "preparation" period. Our wetland mesocosm experiments clearly present that the "equilibration" period that Julian (2018) suggested was done and that it takes several years for the mesocosms to become genuine "ecosystems" in soil, water, and vegetation structure and function (Ahn and Mitsch, 2002; Mitsch et al., 2013).

2.3. Misapplication of controls

The original idea of having a mesocosm treatment that had no vegetation of any kind, in hindsight, was an impossible condition. We attempted it nevertheless in the beginning of the study. Our researchers attempted to remove all vegetation from the three control mesocosms on a weekly basin. But the time requirements for this manipulation plus the turbulence and hence phosphorus export that this practice was causing led us to stop that practice. After that we referred to the control as a "self-design" treatment. After that decision, we noted that the water quality in the "control" outflows began to improve.

Julian's (2018) hypothesis "that if the authors established a maintenance schedule and regime to minimize the disturbances on a regular schedule the treatments may have been managed with minimal impact and investment of time over the course of the study maintaining treatment fidelity" is untenable. Nature abhors a vacuum and would not allow an unvegetated control in the Florida climate and nutrient conditions. We believe that an unplanted yet "self-design" mesocosm is a better control. Furthermore, the focus of the experiment was to test if certain vegetation communities were better than others in improving water quality from the STA outflows. Comparing water quality among different sets of vegetated wetlands even without an unvegetated control was sufficient to meet our study objectives.

2.4. Scalability of mesocosms

It is well known that mesocosms allow low-cost, replicable, experiments that provide useful scientific information that otherwise would not be possible with full scale experiments that would be burdened with cost, lack of easy replication, and ecological complexity. For example, alligators are often the first to visit larger-scale experimental basins in Florida in great numbers, making larger-scale studies difficult. We summarized this comparison of scale 15 years ago in Ahn and Mitsch (2002). Mesocosms are models, and just as with mathematical models, their results should be extrapolated to full scale with caution. In fact, Julian (2018) spends much of this section praising our previous paper (Ahn and Mitsch, 2002) for which we thank him. But he should have read our papers more carefully. We never said that mesocosms' small size and other artifacts prevent them from providing useful scientific results or contributing to management decisions. We were extraordinarily careful in Mitsch et al. (2015) to not extrapolate the mesocosm studies to full-scale extrapolations without a great deal of caution. Our labs have been doing wetland mesocosm studies for 20 years or more and we are quite aware of both the limitations and advantages of mesocosm experiments.

3. Replies to Juston and DeBusk (2018)

Juston and DeBusk's (2018) article was a much better critique in the sense that it came from consultants who have considerable experience with wetland mesocosm studies. Their rebuttal was supported by the "Everglades Agricultural Area Environmental Protection District."

Juston and DeBusk (2018) summarized their concerns in the following three topics, specifically: 1) similar demonstrations of ultralow phosphorus discharges (≤ 12 ppb P) in previous STA mesocosms and full-scale wetland basins have been transient; 2) phosphorus removal rates are always lower in lower concentrations of phosphorus; and; 3) there already exist numerous full and field-scale and back end wetland